Touching nanospace : Atomic Force Microscope coupling with a force feedback manipulation system

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Today, Scanning probe microscopies are widely used in physics, chemistry and biology in order to image surfaces with a great resolution but also more and more as tool to manipulate nano-objets [1] or to modify surfaces at nanometer scale [2]. At the present time, using SPM to manipulate nano-objets is not user friendly and is time consuming. These two weak points are due to the absence of feedback control ***in real time*** of the tip movements and of the tip-surface or tip/nano-object interactions and also to the absence of simulation or virtual reality of the scene in the nanoworld.

Currently, the feedback control of the tip movements and tip-surface/nano-object interactions are made after the ordering action and not during the action itself. In practise, the manipulation of a nano-object required a description step of the tip movement where several parameters must be specified as the tip-surface pressure, the starting and arrival points…

After to check the result of the manipulation, action, an image must be realized. It is also important to notice the absence of movement and scene simulation/emulation in order to test and improve the validity of the ordering action. The same for the determination of the tip-surface or tip-object interactions, an approach-retract force curve must be done, even if this action can induce a total or partial destruction of the nano-object, surface or the tip.

These weak points are mainly due to the use of a ***passive*** feedback control interfaces. The aim of our research work is to realise an active feedback control interface based on an active force feedback control interface which will allow to feel in real time but also to simulate the tip movement and/or tip-surface/nano-object interactions. Our system is constituted of a joystick with three degrees of liberty (X,Y,Z) connected to a computer/simulator. This system allows to manipulate the tip but also to feel the variations of one of the tip parameters as tip-sample force interaction or the oscillating amplitude of the tip ***in real time***. With this ***active interface***, it is then directly possible to know if the movement of the tip is effective and well adapted to the goal.

Coupling to this active force feedback system, a virtual really system will allow to physically implement multi-sensory real-time in-situ interactions, from the nanometre up to the micrometre scale, with real-world objects. This virtual interface allows to simulate (emulate) the result of tip-object interactions and by the way to adjust the tip parameters in order to obtain a successful nano-object displacement during the first real shot.

In the present work, some examples of real time approach-retract curves of the tip vs distance controlling and feeling through the joystick and some simple simulations of tip-object movements/displacements will be shown. An introduction to the questions relative to human behaviour/perception of the nano-world based on very different physics phenomenon through this active system will be address. Finally, the philosophy of our approach and the performance of our system will be compared with the others approaches and systems developed by few others research groups in the world [3].

References

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http://www.cs.unc.edu/Research/nano/doc/biovisit.html
http://www.memagazine.org/backissues/feb01/departments/input_output/input_out.html).

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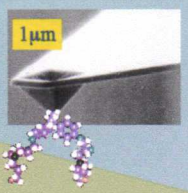
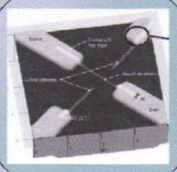
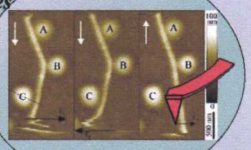


Manipulate nano-objects with SPM?



Passive feedback control interfaces

Many surface scanning
Blind manipulation
Total /Partial destruction of the nano-object, surface or tip



- Not user-friendly
- Time consuming
- No real-time feedback control
- No virtual reality
- No perception: visually tactile acoustically

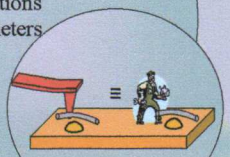
Consequences: Multiple errors, Limited operations, Disappointing quantitative measures

From a nano-tool ...

Manipulations on the real scene [1]

Active feedback control interface

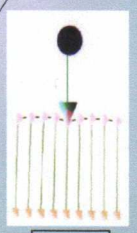
- Real-time interactions feeling
- Real-time simulations
- Adjust the parameters for a successful displacement from the first real shot

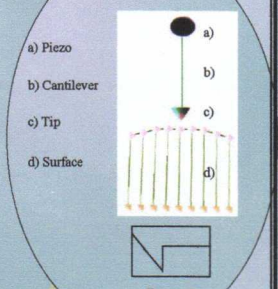


Models for the AFM tip-surface interaction

Developed with Telluris modeler [3]

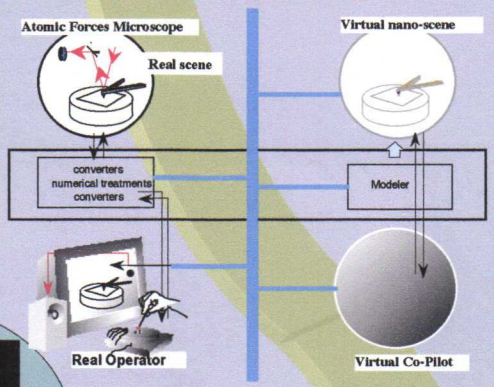
1D Models





Tip-sample and nanoobjects-sample interactions modeled with a Van der Waals potential.

Future Final Architecture

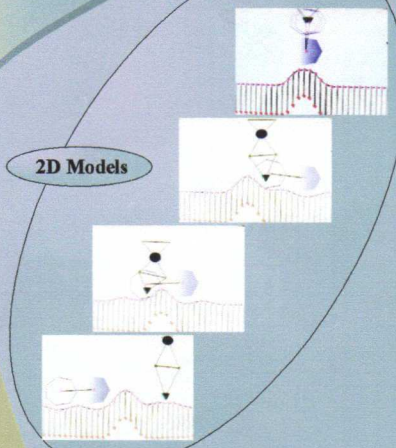


The virtual scene, created from the real one, allows to determine the suitable parameters in order to perform the specified manipulation in the first attempt on the real sample. This action is supported by the virtual co-pilot in real time and with a multi-sensory feedback.

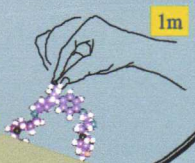
AFM

FFGD [2]

2D Models



... to a nano-worker



CONCLUSIONS

We have succeeded to :

- Control the AFM tip with a FFGD through a basic coupling (modeler)
- Concept the virtual scenes based on physical models of interaction, tested in real time with a FFGD

FUTURE WORK

Link the virtual and real scenes in order to have a complete and complex force feedback manipulation system

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